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*Full Length Research Paper*

# Performance Analysis of Photovoltaic Modules under Shading Effect

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**In this paper, the effect of shading on solar Photovoltaic (PV) models is evaluated by using a simulation model which is able to simulate both the I-V and P-V characteristics curves for PV panels. Four percentages shading states (25%, 50%, 75%, 100%, and without shading) with constant irradiation and temperature degree are taken into consideration of the result part. The results are extracted and simulated using the Matlab software. One-diode equivalent circuit is applied in order to investigate I-V and P-V characteristics of a typical Kyocera 54W and Solara 130W solar modules. The results show that the performance of both models is widely decreased and the models can't charge the batteries if the shading more than 50% for single panel.**

**Keywords:** shading, PV, MPP, Solara, Kyocera, I-V, P-V

## INTRODUCTION

Shading of PV installations has a disproportionate impact on power production (Deline, 2009). For a single-string grid-tied PV system, a shadow can represent a reduction in power over 30 times its physical size. In order to accurately predict the power lost due to shaded conditions, it is necessary to identify the bypass diode placement in the PV modules, as bypass diodes regulate the impact of shading on a particular module or group of cells. With an accurate description of the PV module layout, a single site survey can provide an estimate of shade conditions at one position, and geometric transforms can translate that shade description to any point in the PV array. This process can provide the basis for an accurate simulation of power reduction in a partially shaded PV system.

PV modules are very sensitive to shading unlike a solar thermal panel which can tolerate some shading (solar electric modules, <http://www.wholesalesolar.com>), many brands of PV modules cannot even be shaded by the branch of a leafless tree. Shading obstructions can be defined as soft or hard sources. If a tree branch, roof vent, chimney or other item is shading from a distance, the shadow is diffuse or dispersed. These soft sources significantly reduce the amount of light reaching the cells of a module. Hard sources are defined as those that stop light from reaching the cells, such as a blanket, tree branch, bird dropping, or the like, sitting directly on top of the glass. If even one full cell is hard shaded the voltage of that module will drop to half of its unshaded value in order to protect itself. If enough cells are hard shaded, the module will not convert any energy and will, in fact, become a tiny drain of energy on the entire system. Partial-shading even one cell of a 36-cell module, will reduce its power output. Because all cells are connected in a series string, the weakest cell will bring the others

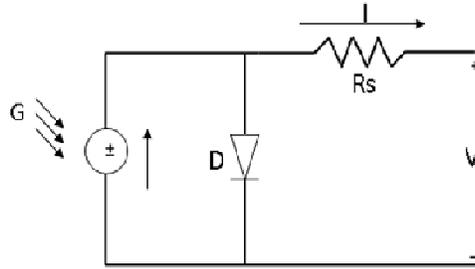


Figure 1. Equivalent circuit of a solar cell

Table 1. Specification of tested modules under 1000 (W/M<sup>2</sup>) irradiation

Parameter	Kyocera	Solara
Isc (Ampere)	3.31	8.18
Voc (Volt)	21.7	21.7
Pout (Watt)	54	100
Brand	Japanese	Germany

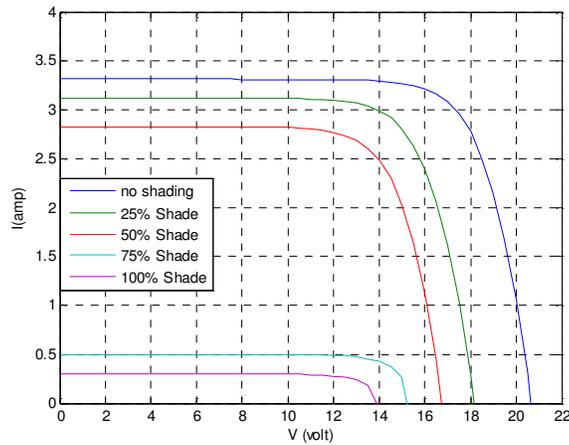


Figure 2. I-V characteristic with shade effect of one Kyocera PV panels (54 W)

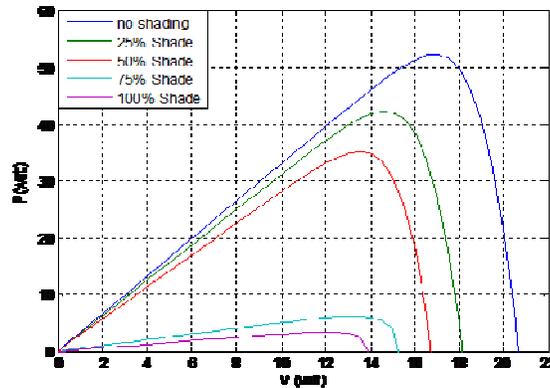


Figure 3. P-V characteristic with shade effect of one Kyocera PV (130 W).

down to its reduced power level. Therefore, whether half of one cell is shaded, or half row of cells is shaded, the power decrease will be the same and proportional to the

percentage of area shaded, When a full cell is shaded, it can act as a consumer of energy produced by the remainder of the cells, and trigger the module to protect

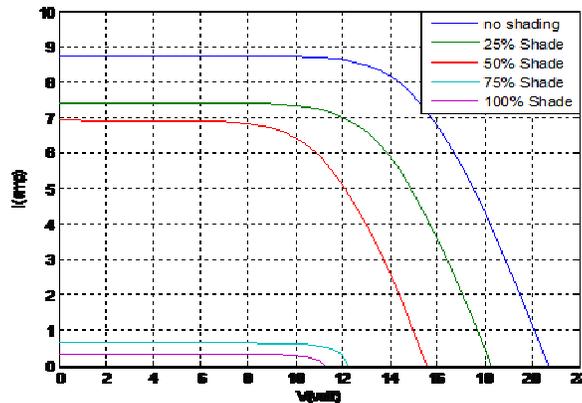


Figure 4. I-V characteristic with shade effect of one Solara PV module (130W)

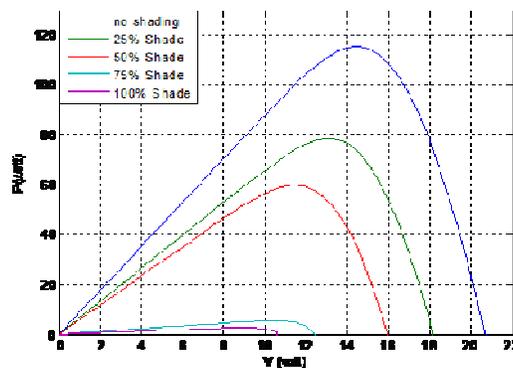


Figure 5. P-V characteristic with shade effect of one Solara PV module (130W).

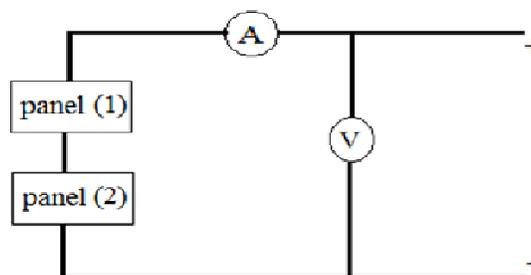


Figure 6. Solar PV panels in series Connection

itself. The module will route the power around that series string. If even one full cell in a series string is shaded, it will likely cause the module to reduce its power level to half of its full available value. If a row of cells at the bottom of a module is fully shaded, the power output may drop to zero. Many notes are obtained from cases analyzed with the simulation like the increase of shading rate over one cell produces higher deformations in the I-V and P-V characteristics, at the same time that displaces maximum power point MPP voltage to lower values. Cells with higher shunt conductance (lower shunt resistance) cause smaller deformation in the resulting I-V

characteristic. The increase in the number of cells per string causes higher deformation in the I-V and P-V Characteristic, displaces the working point to lower voltages and increases power losses, the increase in the number of shaded cells in the same string do not affect MPP, nevertheless when cells are placed in different strings power losses are considerably increased (Alonso-Garci et al., 2006).

The existing Photovoltaic modules in renewable energy research centre (University of Anbar-Iraq) consist of 36 cells. These modules (Kyocera and Solara) are often used for experimental researches. In this experiment PV

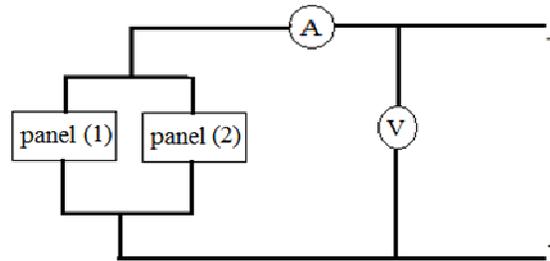


Figure 7. Solar PV panels in parallel Connection

Table. 2. Shading effect in maximum power point (MPP)

Model \ Connection	Shading state	Isc (amp)	Voc (volt)	Module MPP (watt)
One panel Kyocera	No shading	3.31	21.1	54
	25%	3.24	18.49	45
	50%	2.85	17.27	37
	75%	0.51	16.01	7
	100%	0.41	15.2	4
Two parallel panels Kyocera	No shading	6.58	21.7	107.2
	25%	5.95	18.1	90
	50%	3.3	15.7	74
	75%	0.64	12.2	15
	100%	0.4	10	8.2
Two series panels Kyocera	No shading	3.306	43.2	106.4
	25%	3.2	36.1	92
	50%	3.07	32.2	75.35
	75%	0.53	30	18
	100%	0.34	21	11
One panel Solara	No shading	8.81	20.68	116.3
	25%	7.34	17.71	86
	50%	6.95	17.27	67
	75%	0.5	12	7
	100%	0.35	10.4	3
Two parallel panels Solara	No shading	17.75	21.61	234.5
	25%	16.1	17.6	191.9
	50%	15.2	17.27	134
	75%	0.6	12.5	14
	100%	0.35	10.4	7
Two series panels Solara	No shading	8.82	43.12	235
	25%	7.3	36.5	194.87
	50%	6.25	31.42	135
	75%	0.65	24.7	17
	100%	0.45	21.1	9

modules were placed in a dark in order to study their behavior without illumination. Our results contain both experimental with some mathematical calculation used to determine the effect of some the junction parameters through an equivalent circuit model of PV.

### The Photovoltaic Cell Modeling

The simplest equivalent circuit of a single solar cell consists of a photo current source, a diode, and a series resistor describing an internal resistance of cell to the

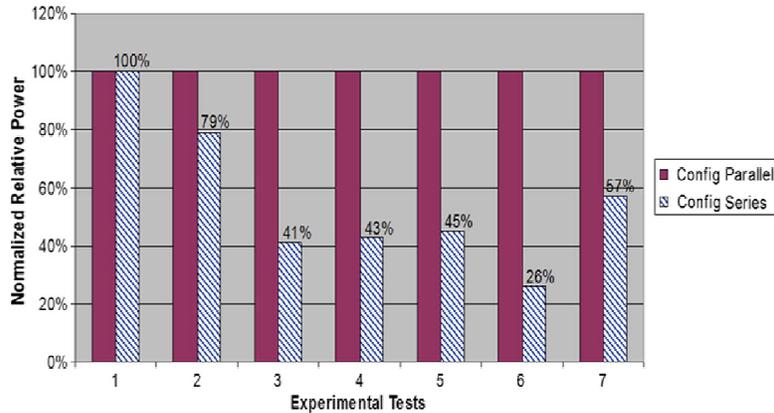


Figure 8. Comparison of power generation between two PV systems.

Table 3. Experimental tests to shading effect

	place	Test description
1	Out of doors	-Area has no shade -panels stationary -panels positioned horizontal
2	Out of doors shown in fig. 14.	-Area shaded by tree -panels constant movement -panels positioned horizontal
3	Out of doors shown in fig. 15.	-Area shaded by tree -panels constant movement -panels positioned at 70 degree to the horizon
4	Out of doors	-Area shaded by tree -panels constant movement -panels positioned at 70 degree to the horizon
5	Out of doors shown in fig. 16.	-Area shaded by railing -panels stationary -panels positioned horizontal
6	Laboratory shown in fig. 17.	-300W artificial illumination source -panels stationary -shading: vertical lines, shading area 53%
7	laboratory	-300W artificial illumination source -panels stationary -shading: squares, shading area 79%



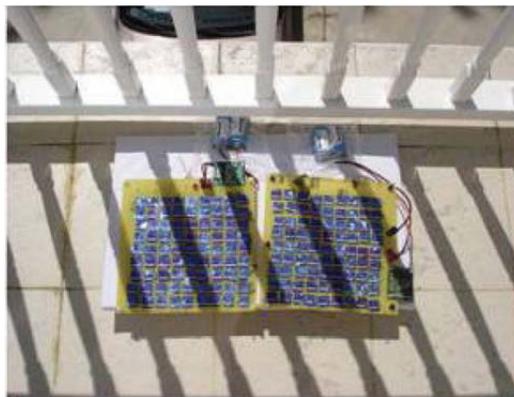
Figure 9. Area shaded by tree, panels constant movement, panels positioned horizontal

current flow. An even more precise mathematical description of a solar cell, which is called the double exponential model as shown in Fig. 1. That derived from

the physical behavior of solar cells constructed from polycrystalline silicon (Mohammed et al., 2011). It considers the calculation of both series along with the



**Figure 10.** Area shaded by tree, panels constant movement, panels positioned at 70 degree to the horizon



**Figure 11.** Area shaded by railing, panels stationary, panels positioned horizontal

junction ideality factor ( $A$ ) and the components of the diode diffusion experimentally collected I-V and P-V curves were introduced into specially designed software that performs numerical (Jihad et al., 2010).

### Simulation result.

Electrical Output power of PV panels is badly affected by shading that caused by clouds and trees and other blocks that prevent sun's radiation with constant irradiation and temperature. In this research it can be shown the effect of panels' efficiency of Kyocera and Solara PV modules by using Matlab program calculation and lab equipments to compute o/p characteristics. The technical parameters for the simulated models are given in table (1).

Four shading cases were chosen in the simulation, these are shading-1 (25%), shading -2 (50%), shading-3 (75%), and shading-4 (100%). The electrical performance of a solar module is represented by the I-V and P-V characteristic curves, I-V characteristic curve represents the current that is provided and depending on the voltage generated for a certain solar radiation The generated current is directly proportional to solar irradiance ( $G$ ),

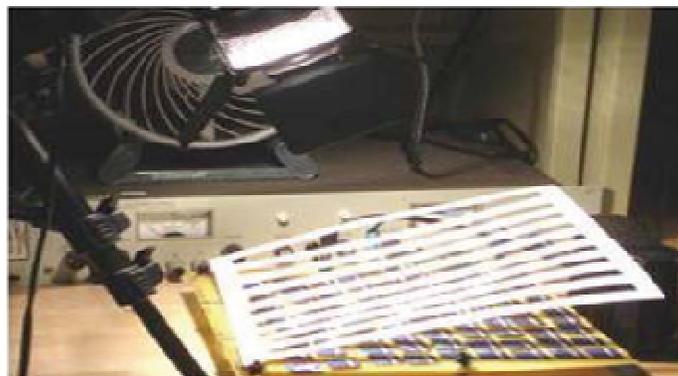
while the voltage reduces slightly with an increasing of shading. P-V characteristic curve represents the amount of power that a panel provides and it depends on the voltage generated for a certain solar radiation.

Many connection ways are used to compute the shading effect on the o/p power. A PV module consists of 36 cells connected and protected by a bypass diode, the data collected in same time and location (In 9<sup>th</sup> of May 2012, 11:39 AM, main park of University of Anbar-Iraq). The I-V characteristic curve for Kyocera model is shown in fig. 2

From fig. 2. it can be seen that the current of PV model decreases as the shading percentage increase from zero to 100%. Note that when the shading percentage is equal to or more than 50%, the o/p of current is so effected and less than amount of current that required to use such model for direct connection to load. Note that if the shading is 75% or 100% the charging current is not enough for charging batteries of 12 V even the shading used is soft shading instead of hard shading. Fig. 3. shows the PV characteristics curves for Kyocera PV module. The power of this module is reduced by about 36% (1-34W / 53 W) as the shading is 50% of the module size with respect to non-shading case. Also; the



**Figure 12.** 300W artificial illumination source, panels stationary, vertical lines 53% shaded area



**Figure 12.** 300W artificial illumination source, panels stationary, vertical lines 53% shaded area

maximum o/p power at non-shading is about 53 W instead of 54 W given in the data sheet of such module this is due to a difference between the simulation modules (which gives an approximate result).

Another test done to single Solara PV panel and shading effect was investigated by I-V and P-V characteristics curves that shown in fig. 4. and fig. 5. respectively. And the practical tested values at the name plate of module. Fig. 4. shows that the voltage generated at shade up to 50% is gradually decreased. As the shading increased to 75% or 100% the o/p voltage will be less than 12V, which means the charging of batteries will stop.

In fig. 5. the maximum o/p power at non-shading is about 118W which is less than the maximum power of this module ( i.e. 130W). The maximum power at 50% of shading is 60W. The maximum power at 50% of shading

is 60W, which is less than the maximum power by about 49% (1- 60W/118W).

From figures above it is clear that Kyocera PV panel is less affected by shading when the same percentage of shading was applied.

The PV panels modules are connected in parallel or serial ways to made the voltage generated is close to (even greater than) the level of voltage of the batteries, and that the current generated is sufficient to feed the equipment and to charge the batteries.

In fig. 6. connecting solar panels in series increases the generated voltage with constant current this connection suitable to overcome the problem of hard drop voltage as a result of shading or any generating efficiency limiter effecter

In fig. 7. Panels connected in parallel to increases the current with constant voltage. The number of panels used

should be increased until the amount of power generated barely greater than the satisfaction of load so it's suitable with directly connection to load

For more explain the shading effect of maximum power point (MPP) with both parallel and series connection show **table. 2**. To prove how shading effect in parallel and series connected PV panels and what a connection has more immunity to shade effect. both Kyocera PV and Solara PV panels was connected in parallel in first time and series in second.

Despite panels is identical and radiation and temperature is constant but there are deference of characteristics between series and parallel note. Show these experimental tests that explained in table 3 and its effect showed in fig. 8. (Lijun et al., 2009).

Even panels that have identical performance ratings will usually display some variance in their characteristics due to manufacturing processes. The actual operating characteristics of two panels from the same manufacturer can vary by as much as  $\pm 10\%$ . Whenever possible, it is a good idea to test the real-world performance of individual panels to verify their operating characteristics before assembling them into an array.

### Shading effect of Batteries charging in PV Systems

Shading effect of batteries should be taken in account. Because a stand-alone photovoltaic systems the electrical energy produced by the PV array can not always be used when it is produced. As the demand for energy does not always coincide with its production, electrical storage batteries are commonly used in PV systems

(URL:[http://www.worldscibooks.com/etextbook/p276/p276\\_chap1.pdf](http://www.worldscibooks.com/etextbook/p276/p276_chap1.pdf)). The primary functions of a storage battery in a PV system are to store electrical energy when it is produced by the PV array and to supply energy to electrical loads as needed or on demand, to supply power to electrical loads at stable voltages and currents. and supply surge or high peak operating currents to electrical loads or appliances. In table 2 from above I-V and P-V characteristics curves to all states and connection ways shading effect of batteries charging is clear.

### CONCLUSION

The observed electrical behavior of solar PV panels of Kyocera PV and Solara PV models under shading effect and cases of connection circuits has been simulated by a computer program, all connection whether parallel or series connection circuits have been explained and which connection is lower effected by shading. The I-V and P-V characteristic must be considered to predict the behavior of a network of solar PV panels (Kyocera PV and Solara

PV). The characteristics curves combination routines could be used with measured data (*e.g.* module I-V and P-V characteristics) making it possible to predict the performance of a real installation. However, for evaluating the behavior of different interconnection circuit configurations, the lumped parameter equivalent circuit model appears to be sufficiently accurate. Electrical mismatches due to process-induced variations in cell's electrical performance, shading effect inevitable in a real installation therefore the behavior of solar cells under this conditions effect should be investigated and taken in account.

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